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Enhanced Ocean Predictability Through Optimal Observing Strategies

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LONG-TERM GOALS

The long-term goal of this research is to develop the requisite technology to design effective observation strategies that will maximize the capacity to predict mesoscale and submesoscale conditions so as to provide the best possible nowcasts and forecasts of oceanic conditions.

OBJECTIVES

There are three tightly integrated objectives. The first is to focus both oceanographic and dynamical systems approaches on developing optimal observing strategies. The common thread linking both approaches is Lagrangian data, so this phase of the work addresses the question of how best to construct Eulerian current maps from these data and how to use the information contained therein to design optimal observing systems.

The second objective will be to design an optimal observing strategy from a synthetic database. Here we will use primitive equation model simulations as the control. The last objective will be to apply this technology to the Gulf of Mexico where both high resolution numerical model results and drifter data are available.

APPROACH

We approach the objectives in this effort by combining the oceanographic methodology of objective Eulerian current reconstruction initiated by Rao and Schwab (1981), Eremeev et al. (1992a and 1992b), and Cho et al. (1998) with dynamical systems techniques of invariant manifold calculations as presented in Poje and Haller (1999). Initially, we intend to utilize model flows where the Lagrangian mixing dynamics are known. Normal Mode Analysis (NMA) developed from prior ONR-supported research will be applied to flows so as to establish benchmark cases for testing observation.
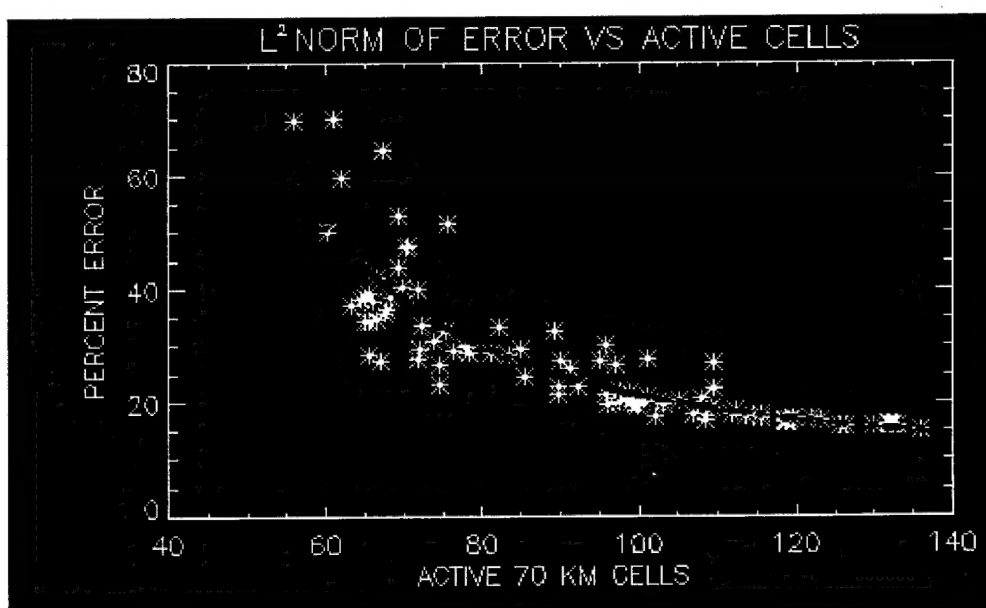
WORK COMPLETED

The emphasis during the first year was on the first objective. In pursuing this objective, a single layer, reduced gravity, double gyre primitive equation model was used to test the accuracy and sensitivity of time dependent Eulerian velocity fields reconstructed using NMA from numerically generated drifter trajectories and climatology. To isolate the accuracy and sensitivity aspects of the reconstruction from the influence of an irregular domain and open boundary, a square basin scale domain was used. The purpose was to determine how much Lagrangian data is needed to capture the Eulerian vector field within a specified accuracy.

The Eulerian fields were found by projecting, on an analytic set of divergence free basis functions (Normal Modes), drifter data launched in the active western half of the basin supplemented by climatology in the eastern domain. The time dependent coefficients were evaluated by least squares minimization and the reconstructed fields were compared to the original model output using measures localized in both physical and spectral space.
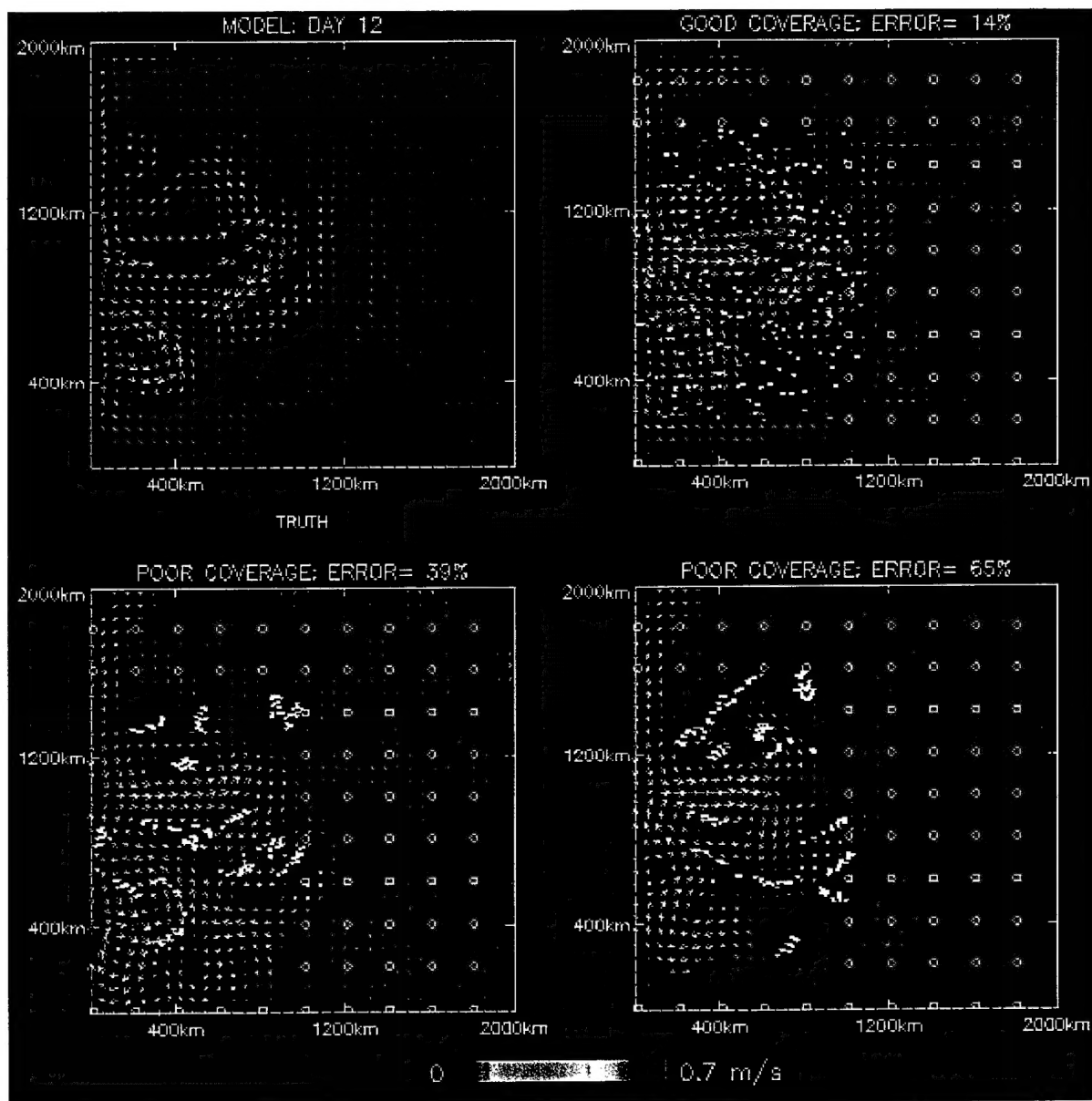
RESULTS

We found that the accuracy of the reconstructed fields depends critically on the spatial coverage of the drifter observations. For the eddy-resolving flow considered, the Normal Mode technique allowed accurate (5-15% error) Eulerian reconstructions in the energetic western basin from drifters representing less than 0.5% of the model grid points. Similar errors were obtained with an equivalent number of Eulerian observations. We concluded that with fixed monetary resources, relatively inexpensive drifter data provides comparable information as moored current meters.

1. Error from projecting 180 drifters on 107 modes related to the mean number of active cells during the 50 day reconstruction period. The linear correlation between the ordinate and abscissa $^{(-2.6)}$ is 0.87.

Accuracy of the reconstructed vector field depends significantly on the spatial coverage of the drifters. In lieu of computing the spatial decorrelation function of the model truth, we rely on the Rossby radius of deformation to delineate a homogeneous spatial decorrelation scale and introduce the concept of an "active" cell. For purposes of coverage, a cell is said to active if it contains at least one drifter. For the flow considered here, the size of the cell corresponds to two Rossby radii. Figure 1 shows the relation between reconstruction error (normalized kinetic energy of the difference field) and the mean number of active cells. Figure 2 shows reconstructions for a good coverage deployment and two poor coverage deployments. Data voids cause the structure of small-scale basis functions to appear in the reconstruction.

2. Reconstructed velocity fields for three different deployments, each of 180 drifters. Solid white dots locate the drifter positions and open circles locate the 65 climatology sample points.

IMPACT/APPLICATIONS

The immediate application of this technology will be to Rapid Environmental Assessment (REA). In addition to the traditional military interest in REA, civilian applications in environmental crisis management ranging from pollution monitoring and containment to risk assessment for hazardous waste operations, will increase substantially in the next few years.

Results obtained thus far are generic in that the spatial coverage and comparative quality issues of the Lagrangian data apply to open and arbitrarily shaped domains. Accuracy issues, of course, will differ in specifics depending on the knowledge available about the "true" flow.

TRANSITIONS

The methodology in this study will be used to assess the predictive capability of a high resolution Princeton Ocean Model (POM) of the Gulf of Mexico in a collaborative effort with Lakshmi Kantha at the University of Colorado. Additionally, this methodology was used in a Ph.D. dissertation by LCDR William Schultz titled, "Ocean Surface Maps from Blending Disparate Data through Normal Mode Analysis," at Old Dominion University. In this effort, MODAS was used in combination with NMA to provide nowcasts of the Texas-Louisiana Shelf with drifter and mooring data.

RELATED PROJECTS

The nowcast technology is being utilized to investigate HF radar data, provided by Jeff Paduan at the Naval Postgraduate School, in Monterey, CA through another ONR project N00014-99-1-0052.

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PUBLICATIONS

Toner, M., A. C. Poje, A. D. Kirwan, Jr., C. K. R. T. Jones, B. L. Lipphardt, and C. E. Grosch, Reconstructing basin-scale Eulerian velocity fields from simulated drifter data, *J. Phys. Oceanogr.*, submitted.

Old Dominion University Research Foundation

November 5, 1999

Office of Naval Research
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Reference: **Final Report for Office of Naval Research Grant N00014-99-1-0054**
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Dear Mr. Sandgathe:

Enclosed please find three copies of the above referenced final report entitled "Enhanced Ocean Predictability through Optimal Observing Strategies" for the period ending September 30, 1999. This report is submitted on behalf of Dr. A. D. Kirwan, Principal Investigator and Michael S. Toner.

Should you have any questions or need anything further, please feel free to contact me at 757-683-4293 extension 615.

Sincerely,

Linda K. Clarke
Grant and Contract Administrator

/krr

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